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Interaction between structural, evolutional and functional directions in landscape studies[1]

Relacje pomiędzy strukturalnymi, ewolucyjnymi i funkcjonalnymi kierunkami studiów krajobrazowych

Abstrakt: Współczesne studia krajobrazowe są skomplikowanym, zróżnicowanym wewnętrznie systemem teoretyczno-metodologicznym. Za jego rdzeń autorzy uważają badania struktury, funkcjonowania i ewolucji krajobrazów. Rozwój wymienionych kierunków nauki powinien zmierzać w kierunku matematyczno-fizycznym.

W latach 1994–2004 w Katedrze Geografii Fizycznej i Studiów Krajobrazowych Uniwersytetu Łomonosowa w Moskwie prowadzono badania organizacji czasoprzestrzennej krajobrazów morenowych strefy lasów borealnych. Szczególny nacisk położono na wzajemne zależności pomiędzy strukturą, ewolucją i funkcjonowaniem krajobrazów.

Do głównych poruszonych problemów należały:

– określenie hierarchicznych poziomów zróżnicowania rzeźby jako elementu determinującego rozkład ciepła, wilgoci, migracji wodnej i współczesną morfostrukturę krajobrazu;

– badania wielkoskalowe na mapach i profilach – stworzenie modelu struktury przestrzennej terenu;

– próba określenia relacji między komponentami krajobrazu środkowej tajgi jako parametru struktury pionowej krajobrazu;

– konstrukcja regionalnego modelu ewolucji krajobrazu badań w holocenie;

– identyfikacja rytmów i określenie tempa ewolucji krajobrazu w holocenie (na przykładzie głównego procesu krajobrazotwórczego – formowania torfowisk);

– charakterystyka długookresowych zmian głębokości zwierciadła wody i pH gleb;

– określenie długookresowych rytmów produkcji na różnych poziomach hierarchicznych krajobrazu w celu wskazania synchronizacji w funkcjonowaniu krajobrazów.

Słowa kluczowe: struktura, funkcjonowanie, ewolucja krajobrazu, strefa lasów borealnych

Key words: structure, functioning, evolution of landscape, boreal forest zone

The present-time landscape studies are a system of fundamental, methodological and applied directions of science with great difference in their development. The nucleus of this science is the parts studying the structure, functioning and evolution of landscapes. The potential of their development can be realized based on physical-mathematical direction.

We have many examples of studies that belong to one of these three directions. But it's hard to give an example of the large-scale study where all of

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them – structural, evolutional and functional were implemented together. The conclusion is that although the studying of structure, functioning and evolution of landscapes is the basis for studying of spatial-temporal organization of landscapes, the problem of synthesis in landscape has appeared from the division of these three directions.

All in all the differentiation of these directions and even their transformation into independent sciences is an ordinary fact. Modern geomorphology and soil science experience is the same problem. The problem is: when we declare that landscape studies play the main role in the system of physical geography science, that landscapes are systems, we must present examples and results of researches using all kinds of field measures and mathematical methods of data processing.

From 1994 to 2004 the research on spatial-temporal organization of local (in-landscape) geographical systems was carried out by Chair of Physical Geography and Landscape Studies. The interaction between structure, evolution and functioning of moraine landscapes of boreal forest zone were considered.

The primary goals of research include:

– Revealing of hierarchical levels of a relief as the matrix determining character of redistribution of heat, moisture and water migration of substance and modern morphological structure of a landscape;
– Large-scale landscape mapping and profiling – creation of a model of spatial structure of territory;
– Definition of intercomponental relations in middle-taiga landscape as parameter of its vertical structure;
– Construction of regional model of evolution of an investigated landscape in Holocene;
– Revealing of rhythms and definition of velocity of evolution of a landscape in Holocene (intensity of the basic physical-geographical process – bog formation);
– Definition of long-term dynamics of depth soil and subsoil water tables and pH-parameter in soils;
– Revealing the in-centennial rhythms of production process at various hierarchical levels of a landscape to find out the landscapes synchronous on functioning.

The landscape within the range of research is characterized as structural-erosion-moraine plain formed by binary deposits of glacial and limnoglacial genesis at superficial occurrence and Perm marls with a combination of birch-pine-spruce woods on podsolic soils, oligotrophic and mesotrophic bogs on peat-gley soils.

The landscape structure of territory is reproduced on the basis of mapping in scales 1:10 000–1:100 000 and landscape transects (in the east part of range)

with regular step of 25 m, with 325 points of the complex description, with step of levelling of 12.5 m. General extent of a transect is 8125 m.

Yu.G. Puzachenko has carried out connected fractal and the multivariate mathematical analysis of the results of levelling of a structure. In addition the relief was removed from topographical maps of scales 1:10 000 and 1:50 000 on the transect by extent of 21 kms. The correlation between the linear sizes of forms of a relief with a hierarchical level was determined (fig.1). Five hierarchical levels with the minimal sizes of structures are allocated: 1–33.75; 2– 52.5; 3–87.5; 4–140; 5–375 m; and 4 for the map: 1–800 m; 2–1750; 3–3000; 4–7500 m.

The spatial hierarchical structure of a relief grows out actions of the uniform factor with fractal dimension 1.5 and meets the fault-block organization of territory. The combination of blocks and lineaments creates a basis for in-landscape differentiation. At high hierarchical levels lineaments are the matrix for erosion network, and at low levels – the downturn occupied with bogs or "channels" of unloading of subsoil waters.

Irrespective of it, in a field within the limits of a structure borders facies and other morphological parts of a landscape were carried out. Comparison of hierarchical levels of relief and landscapes of middle-taiga a glacial landscape has shown, that the number of hierarchical levels of a relief automatically does not mean the amount of hierarchical levels of landscapes (tab.1).

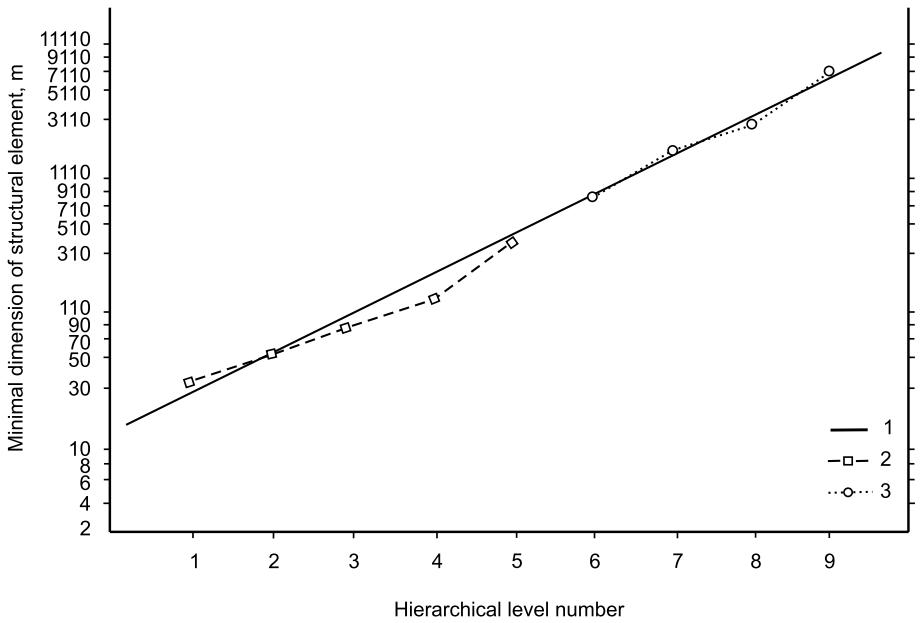

Fig. 1. Relations between hierarchical levels of relief and it's linear dimenstions

Tab. 1. Hierarchical levels of relief and geosystems (linear dimension within landscape profile)

Hierarchical levels of relief (fractal and multivariate analysis	Hierarchical levels of geosystems (nature estimates), m				
	64.8	187.9	229.2	680	2700
33.8	+				
52.5	+	+			
87.5	+	+			
140	+	+	+		
375		+	+	+	
720				+	
1300					+
4300					+

Conclusion: facies as the geosystems are not deduced from one component, and the interaction of separate components not usually form the emergent components.

The spatial structure of a landscape is formed during functioning. The relief and substrate matrix in which streams of substance and energy in a landscape "are initially enclosed", substantially limits a variety of conditions of components with smaller characteristic from time to time (ground, vegetation, waters). During evolution of a landscape in an ideal case there is a gradual mutual adaptation of components, and in each of concrete geomorphological situations the inherent specific combination of properties of mobile and inert components is formed only to it. However by virtue of different characteristic time components of a landscape can not develop absolutely synchronously. Hence, their mutual adaptation is a long-term process.

As a result of functioning of a landscape, rigid correlations between mobile and inert components explain only about half of all variety of their combinations.

While studying the functioning of geosystems besides seasonal and long-term dynamics of subsoil waters and soil pH conditions, the attention was paid to natural spatial and time variability of parameters of functioning of geosystems, on synchrony-asynchrony of productivity process inside a landscape.

Natural variability in geosystems' functioning specifies tolerable invariant deviations and designates characteristic time of processes, i.e. as a whole is one stability from the major characteristics of natural geosystems (tab. 2).

The main conclusion: fluxes in geosystem show lower variability as compered with out-of-geosystem fluxes.

Definition of in-landscape existential variability of productivity process (a time interval of 60–100 years) with the purpose of revealing synchrony-asynchrony of landscape functioning and their subsequent typology

and construction of hierarchical levels on a degree of similarity of landscape on dynamics of a gain can be considered on the one hand as rather independent problem, and with another – connected with an evolutionary direction of research.

Tab. 2. Geosystem fluxes long-term variability within Dvinsko-Mesen plain

Flux	Units	Period, years	Dispersion,	Coefficient of variation, C_v
In-geosystem fluxes				
Radiation balance	M Joule/ m^2*year	1960–1980	90	0.08
Precipitation	mm/year	1936–1992	133	0.19
Air temperature, July	K	1936–1992	2.0	0.007
Out-of-geosystem fluxes				
River flow	mm/year	1936–1966	61.4	0.30
Radial increment of trees:				
Pines in conditions of bilberry--greenmoosed pine forest	mm/year	1941–2000	0.29	0.24
Pines in conditions of oligotrophic marsh	mm/year	1951–2000	0.31	0.31
Spruces in conditions of sphagnous-moosed spruce forests	mm/year	1941–2000	0.26	0.26

The dendrochronological method was implemented, with the subsequent automated calculation of a radial increment of trees. Cluster analysis allowed to break set of 200 trees on hierarchically co-ordinated levels on dynamics of an annual increment. Six levels that directly do not contact hierarchical levels of landscapes allocated with a traditional field way.

After that the analysis of synchrony of functioning of all chronologies with application of factors of correlation and gleichlaeufigkeit (Huber 1943) was executed. According to this analysis, all geosystems occupying independent sites, irrespective of their degree of hydromorphism are synchronous. Asynchronous were the geosystems concerning directly to valleys of the small rivers and creeks.

The cycles in tree-ring chronologies were found out by Fourier spectral analysis. The 11-year cycle presented in all chronologies, moreover 22-year and 5–6-year were also detected in few of them.

The problems of palaeolandscape research included:

– Construction of regional models of evolution of a landscape in Holocene, including in prepotent and subdominant natural boundaries, with the characteristic abiotic and biotic components of landscape;
– Calculation of horizontal and vertical speeds of bog-forming for the different periods of Holocene and definition of a ratio of factors of self-development of landscapes, exogenous and anthropogenic;

– Revealing of a role of forms of micro-and mesorelief (an initial mineral surface in speed of accumulation organogenous horizon and a role organogenous horizon in transformation of initial morphological structure of a landscape);
– The forecast of development and self-development of bog-forming of landscapes and transformations of its morphological structure.

Using five spore-pollen diagrams, the generalized regional circuit of change of subtypes of landscapes in Holocene was created.

The results of 17 datings on 12 sections, located in different geosystems were used for the estimation of speeds of bog-forming. Background values are on the average equal 0.14–0.18 mm per year. Correlation of age and capacity of peat is high and is described by the linear equation with factor of determination of 87%. Process of bog-forming has began in AT-2, 6900 years ago, and since then it did not stop, making essence of self-development of a landscape (fig. 2). New centers of bog formation appeared more often in SB-3 and in a small glacial age – SA-P.

Important component of paleolandscape research is analysis of organic layer thickness dependence on mineral surface macro-, meso- and microrelief. This analysis reveals the role of phase structure in landscape evolution and links together in certain extent evolutional and structural landscape schools.

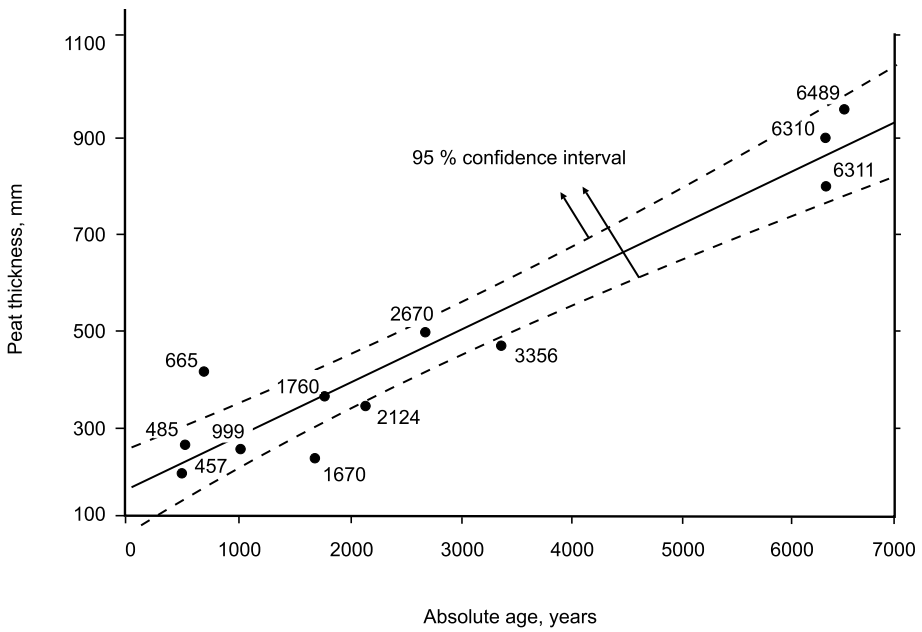

Fig. 2. Peat thickness and absolute age dependence

The dependence between swamping and mesorelief structure was determined (fig. 3). In the mean time of relatively constant vertical speed growth determined by climatic conditions, lateral speed is low on slopes while accelerates on flat surfaces. Swamp growth causes rise of groundwater level on contiguous territory. Swamping process becomes stable and continuous after its organic layer gets thickness of 15.7 sm.

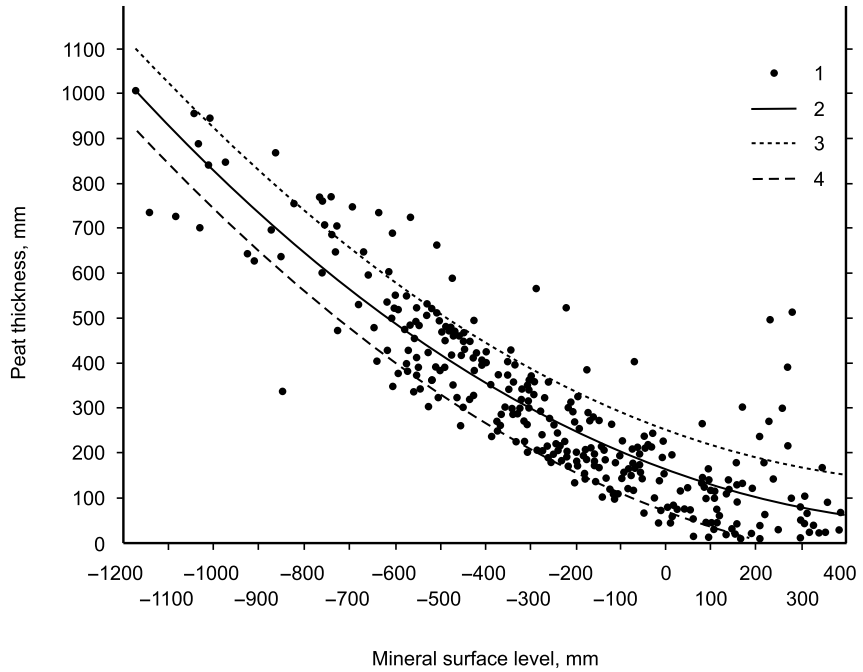

Fig. 3. Dependence between organic layer thickness and mineral surface level on mesotrophic swamp and in contiguous forest. Zero level corresponds to actual swamp surface. 1 – sample points; 2 – regression line for quadratic equation; 3 and 4 – upper and lower confidence interval

Conclusions

1. The combination of three approaches has allowed to detect, that during evolution of a landscape there is a transformation of initial morphological structure in which formation plays the important role even in flat territories that belong to the neotectonic factor.

2. For in-landscape geosystems about half of variability of soil conditions and vegetation is rigidly determined by a geological-geomorphological basis, but at the same time intercomponental relations always suppose some freedom for self-development.

3. Rhythms of evolution of landscapes in Holocene and modern in-centennial rhythms of productivity process as a whole are synchronous, and separate displays of asynchrony are caused by a local variation of soil pH conditions.

4. Speed of a process of peat-formation and in the south of the Arkhangelsk area (oligotrophic bogs) is canal to 0.29–0.31 mm per year.

5. Palaeolandscape studies provide revealing integrated physical-geographical process which should be described through balance of substance or be characterized by speed.

6. In middle-taiga landscape the key role is played with the processes of self-development caused by bog-formation which speed is corrected both climatic fluctuations and local pH conditions of marshes. Their geochemical heterogeneity reflects the history of development and is connected to joint action of abiotic and biotic factors which importance varied during evolution.

7. Interaction of structural, evolutionary and functional directions solves the problem of landscape synthesis and overcomes break between the basic branches of landscape knowledge.